MODULO MEETING

# Evolution of chemical abundances and dust grain populations

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# Modeling chemical evolution with a toy-model

Valiante, Schneider, Bianchi & Andersen (2009)

$$\frac{dM_*(t)}{dt} = \mathrm{SFR}(t) - \frac{dR(t)}{dt}$$

$$\frac{dM_{\mathrm{ISM}}(t)}{dt} = -\mathrm{SFR}(t) + \frac{dR(t)}{dt} + \frac{dM_{\mathrm{inf}}}{dt}$$

$$\frac{dM_Z(t)}{dt} = -Z_{\mathrm{ISM}}(t)\mathrm{SFR}(t) + \frac{dY_Z(t)}{dt}$$

$$\frac{dM_d(t)}{dt} = -Z_d(t)\mathrm{SFR}(t) + \frac{dY_d(t)}{dt} - \frac{M_d(t)}{\tau_d}$$

$$\frac{\mathrm{d}M_{\mathrm{inf}}}{\mathrm{d}t} = A\left(\frac{t}{t_{\mathrm{inf}}}\right)^2 \exp\left(-\frac{t}{t_{\mathrm{inf}}}\right).$$

$t_{inf} = t_{ff}/4$

$A = M_{gas,in}/2\ t_{inf}$

Keres et al. (2005); Salvadori et al. (2009)

$$\frac{dR(t)}{dt} = \int_{m_*(t)}^{100M_\odot} (m - \omega_m(m, Z_{\mathrm{ISM}}))\phi(m)\mathrm{SFR}(t - \tau_m)dm$$

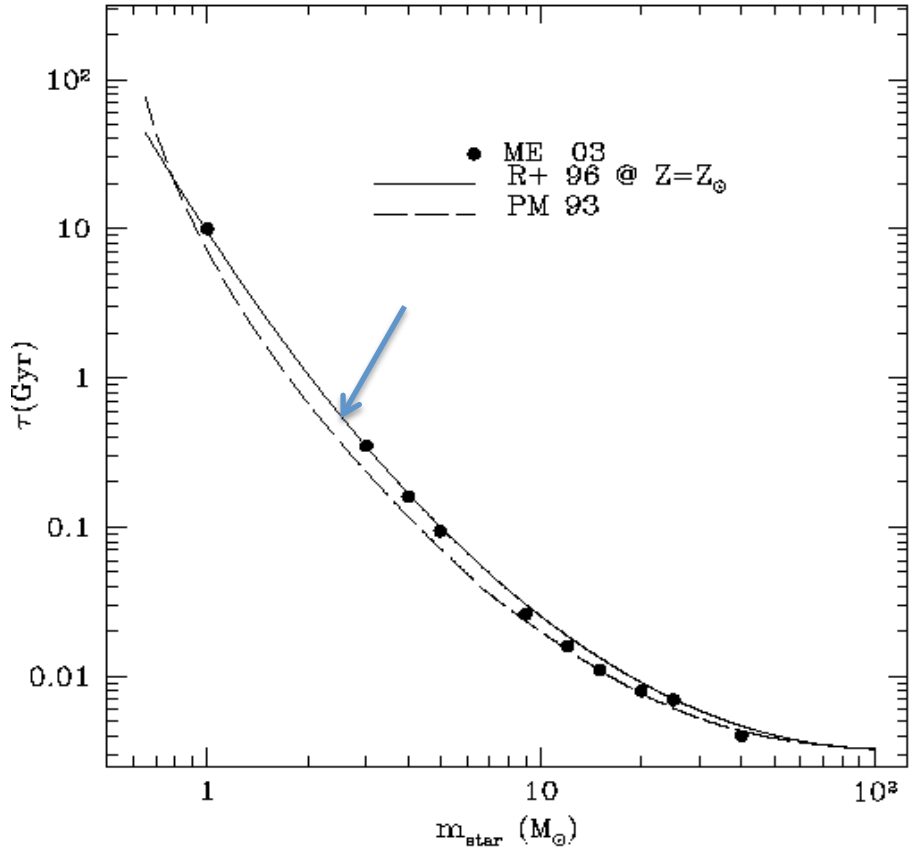
$$\frac{dY_Z(t)}{dt} = \int_{m_*(t)}^{100M_\odot} m_Z(m, Z_{\mathrm{ISM}})\phi(m)\mathrm{SFR}(t - \tau_m)dm$$

$$\frac{dY_d(t)}{dt} = \int_{m_*(t)}^{100M_\odot} m_d(m, Z_{\mathrm{ISM}})\phi(m)\mathrm{SFR}(t - \tau_m)dm$$

$\Phi(m)$ Salpeter IMF [0.1-100] $M_\odot$

$\tau_m$ stellar lifetime (Raiteri et al. 1996)

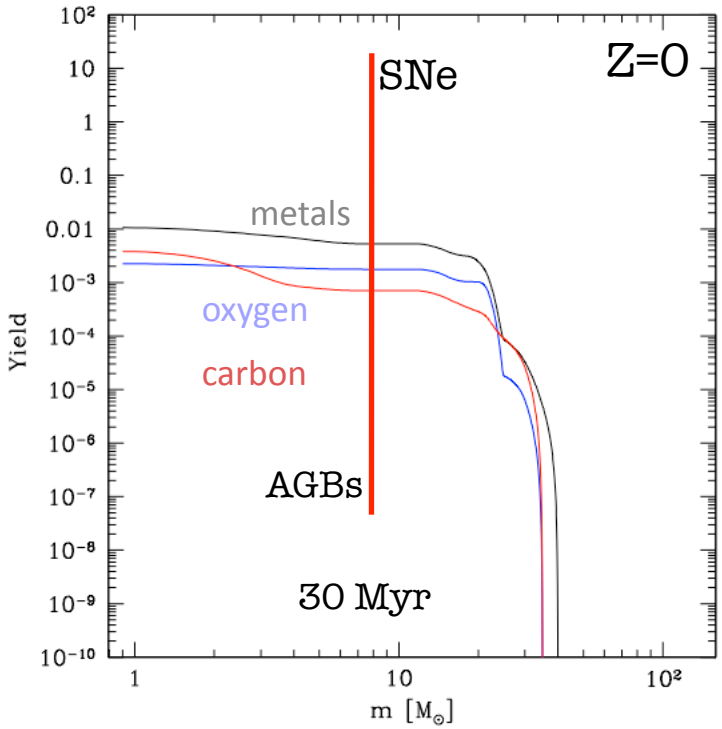
# stellar lifetimes and IMF

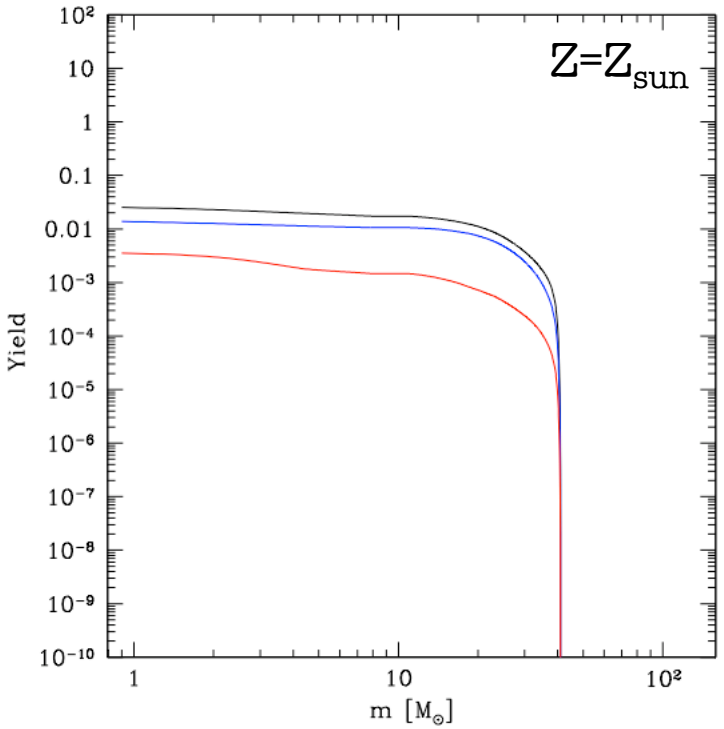



$$\Phi(m) = \frac{\mathrm{d}N}{\mathrm{d}m} \propto m^{-1+x} \exp(-m_{\mathrm{cut}}/m), \qquad (2)$$

with $x = -1.35$, $m_{\mathrm{cut}} = 0.35\,\mathrm{M}_{\odot}$ and $m$ in the range $[0.1\text{–}100]\,\mathrm{M}_{\odot}$

# metal yields

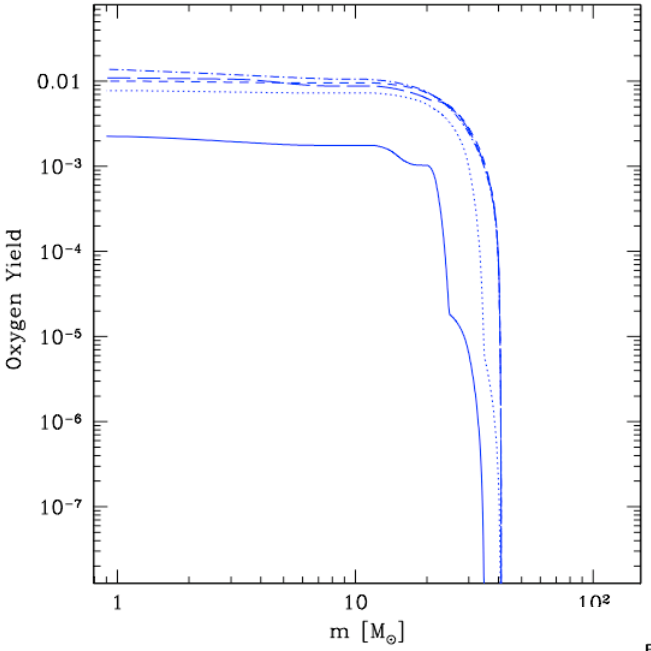


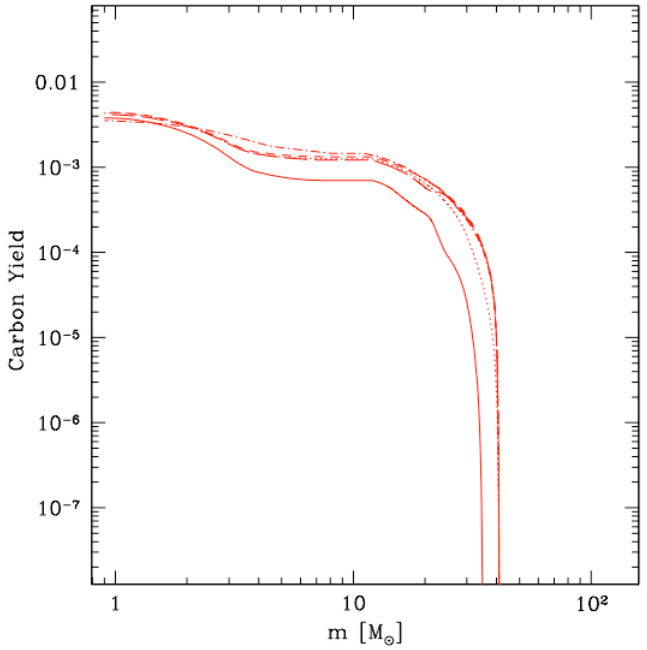



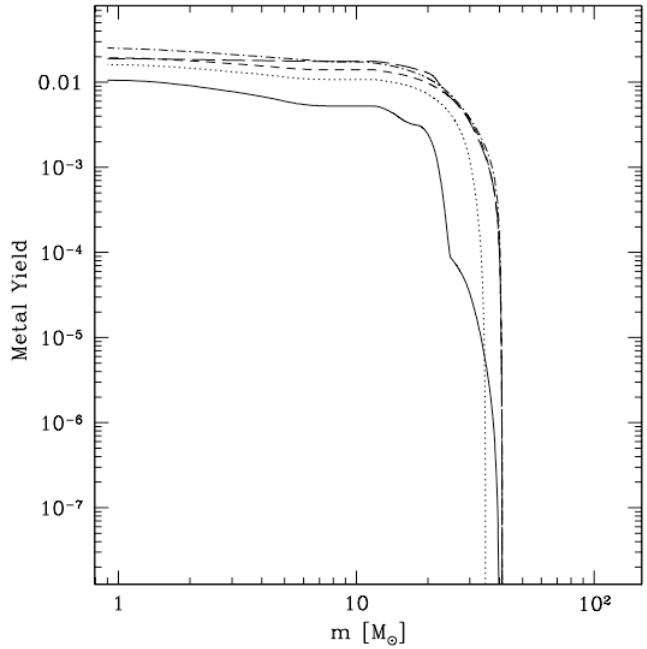

time

Woosley & Weaver (1995)
Van den Hoek & Groenewegen (1997)

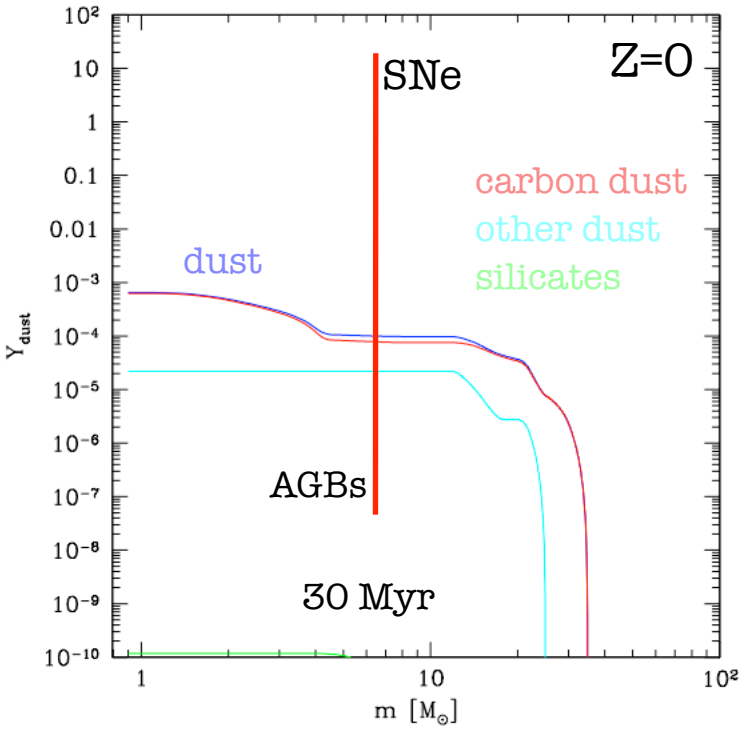
# metal yields

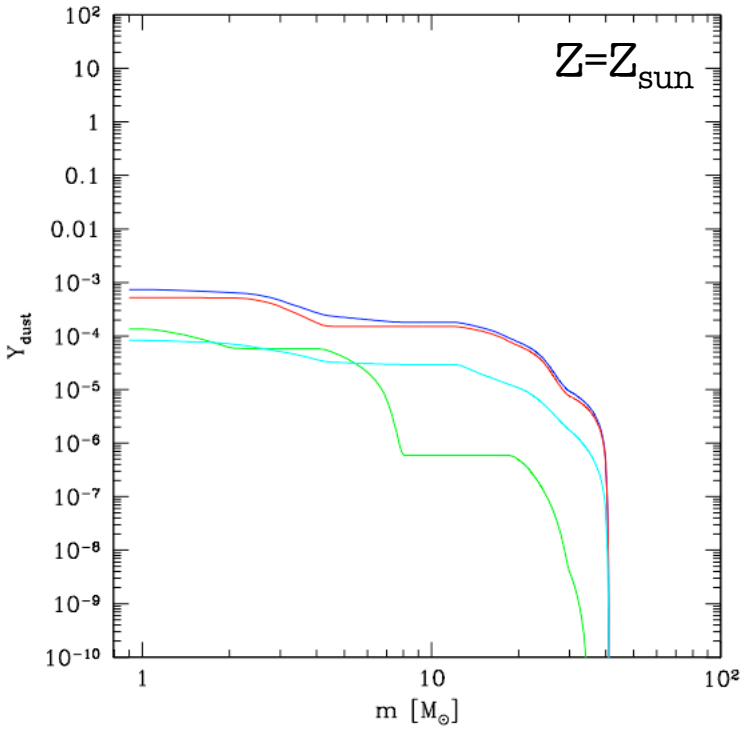


# Dust yields




Bianchi & Schneider (2007)
Zhukovska et al. (2008)

# initial conditions

(1) Spherical extragalactic HII regions

Initial available gas mass, $M_{gas} = 10^7 M_{sun}$

dense = 1e5 $cm^{-3}$
compact = 3e3 $cm^{-3}$
diffuse = 1e2 $cm^{-3}$

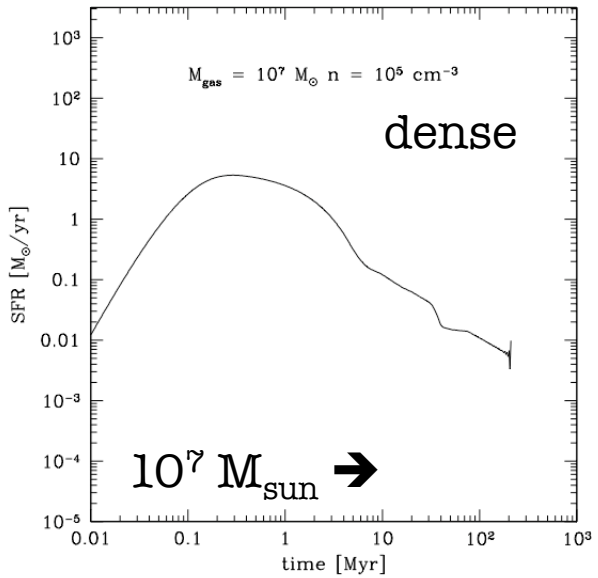
(2) Ultra-luminous-like spherical scaled-up extragalactic HII regions:

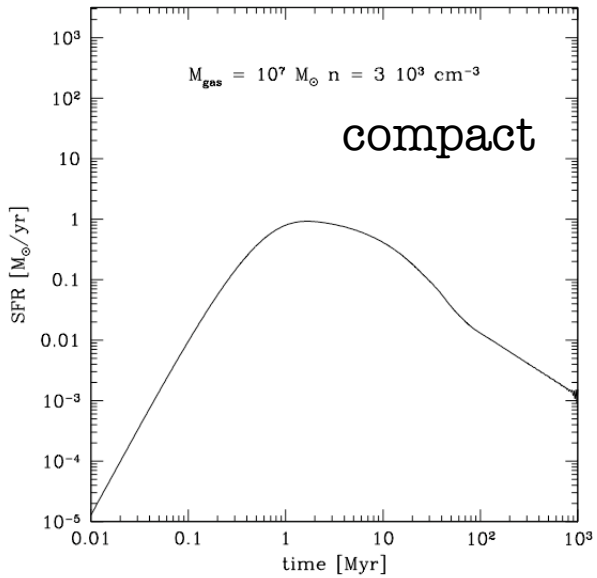
Initial available gas mass, $M_{gas} = 10^9 M_{sun}$

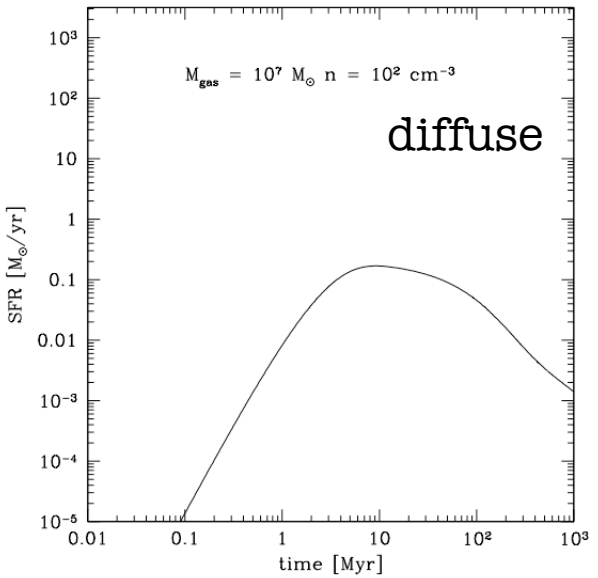
dense = 1e5 $cm^{-3}$
compact = 3e3 $cm^{-3}$
diffuse = 1e2 $cm^{-3}$

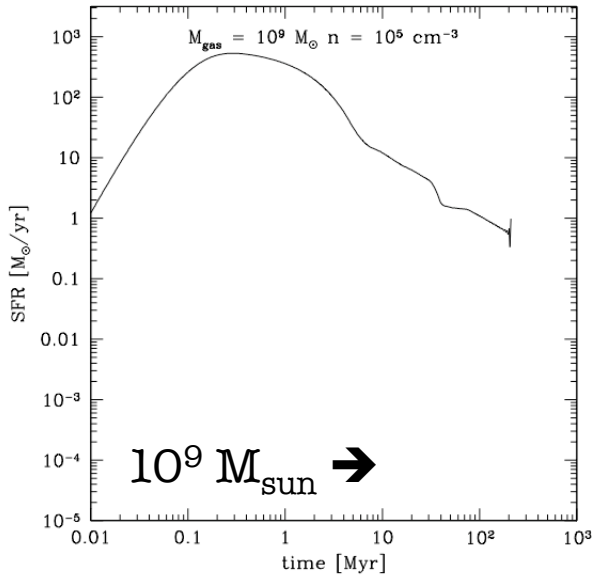
$SFR = eff * M_{gas} / t_{ff}$ with eff = 0.1

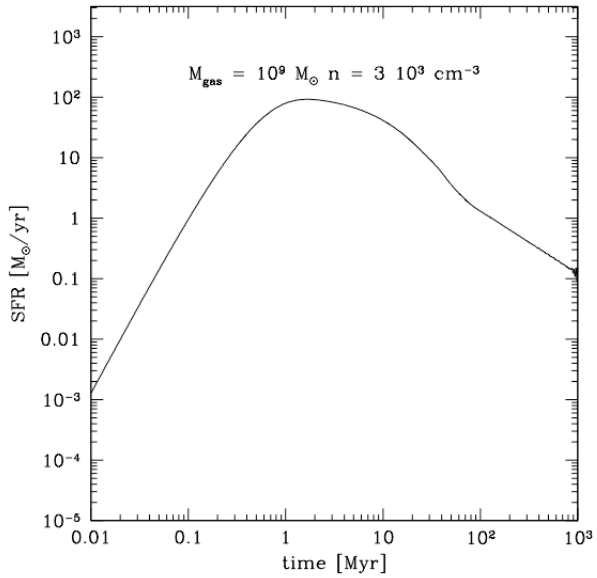
# star formation histories

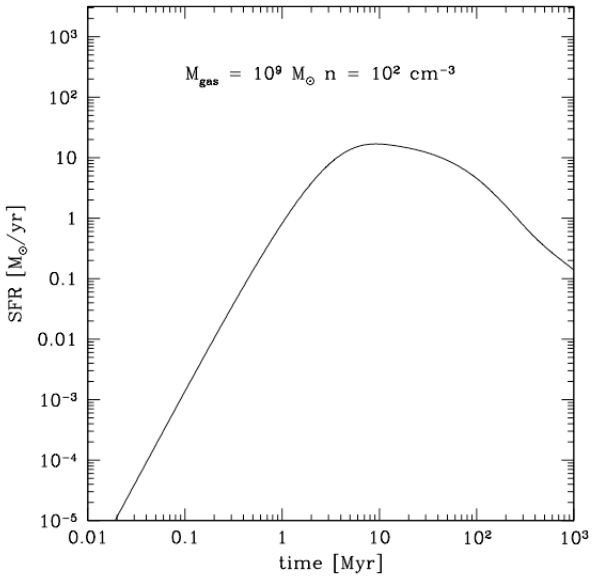


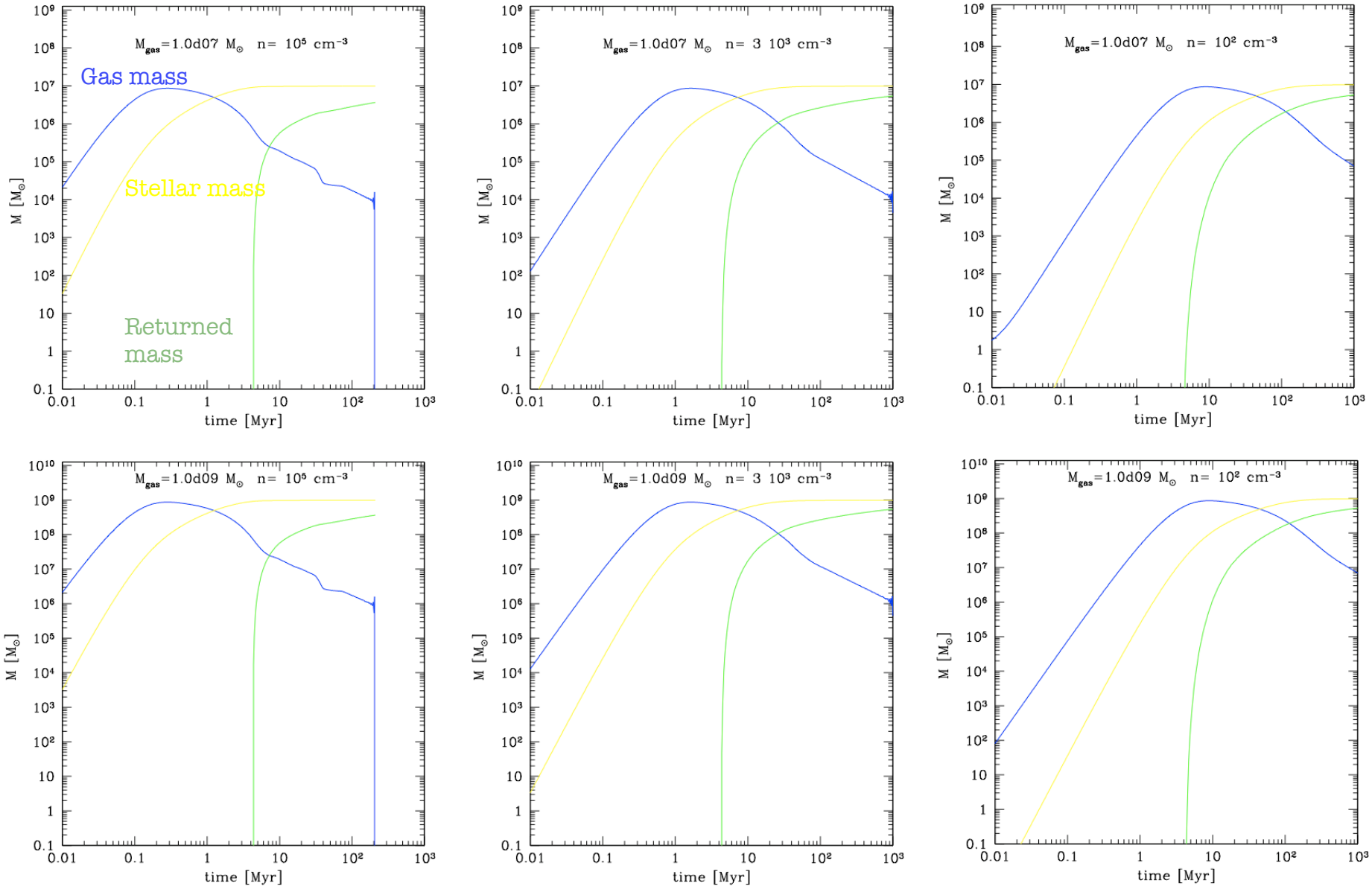



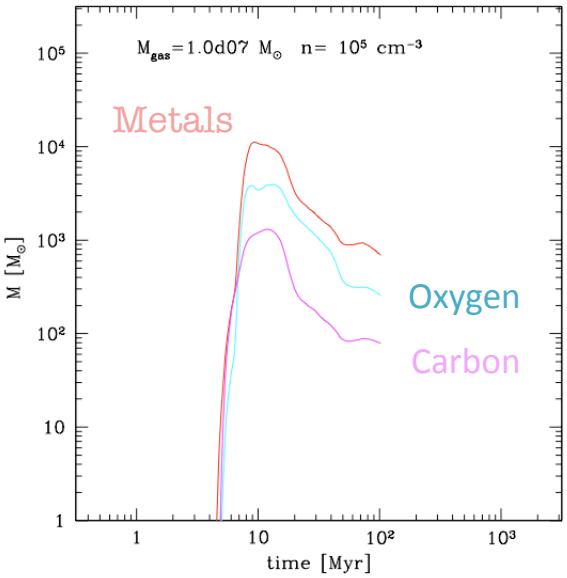



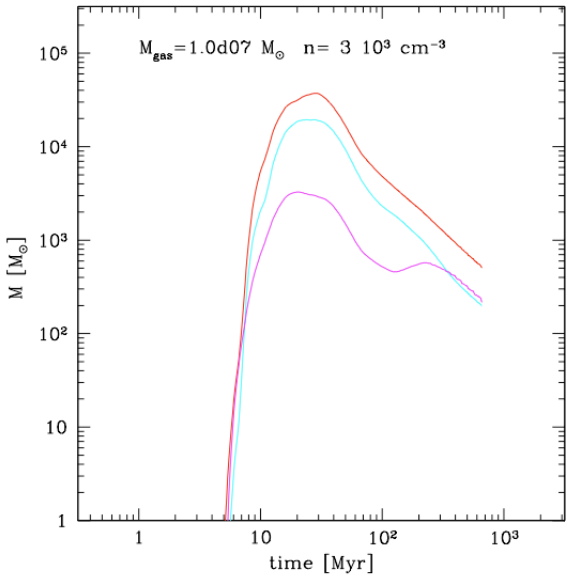



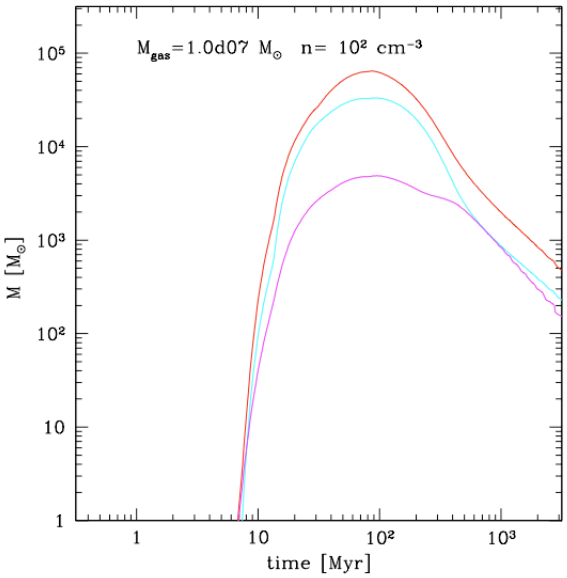
# gas and stellar mass evolution

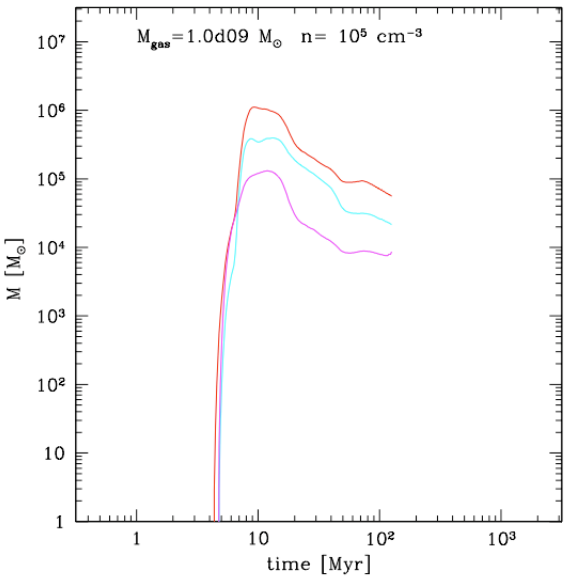


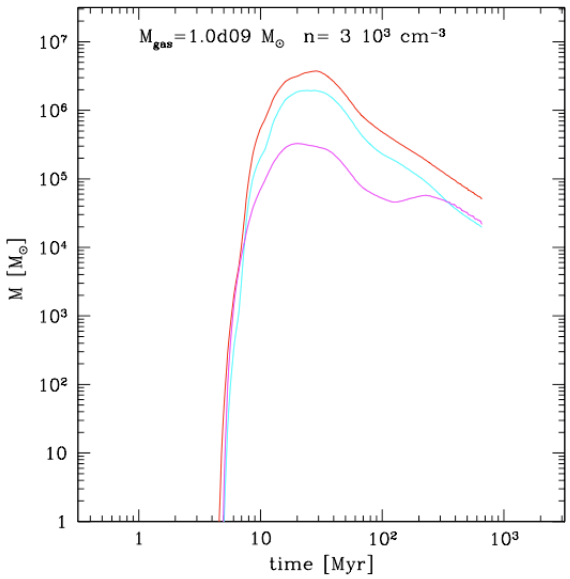
# evolution of metals

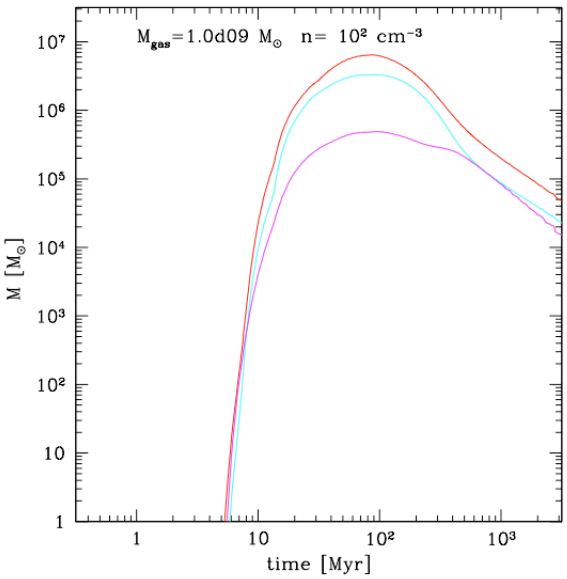


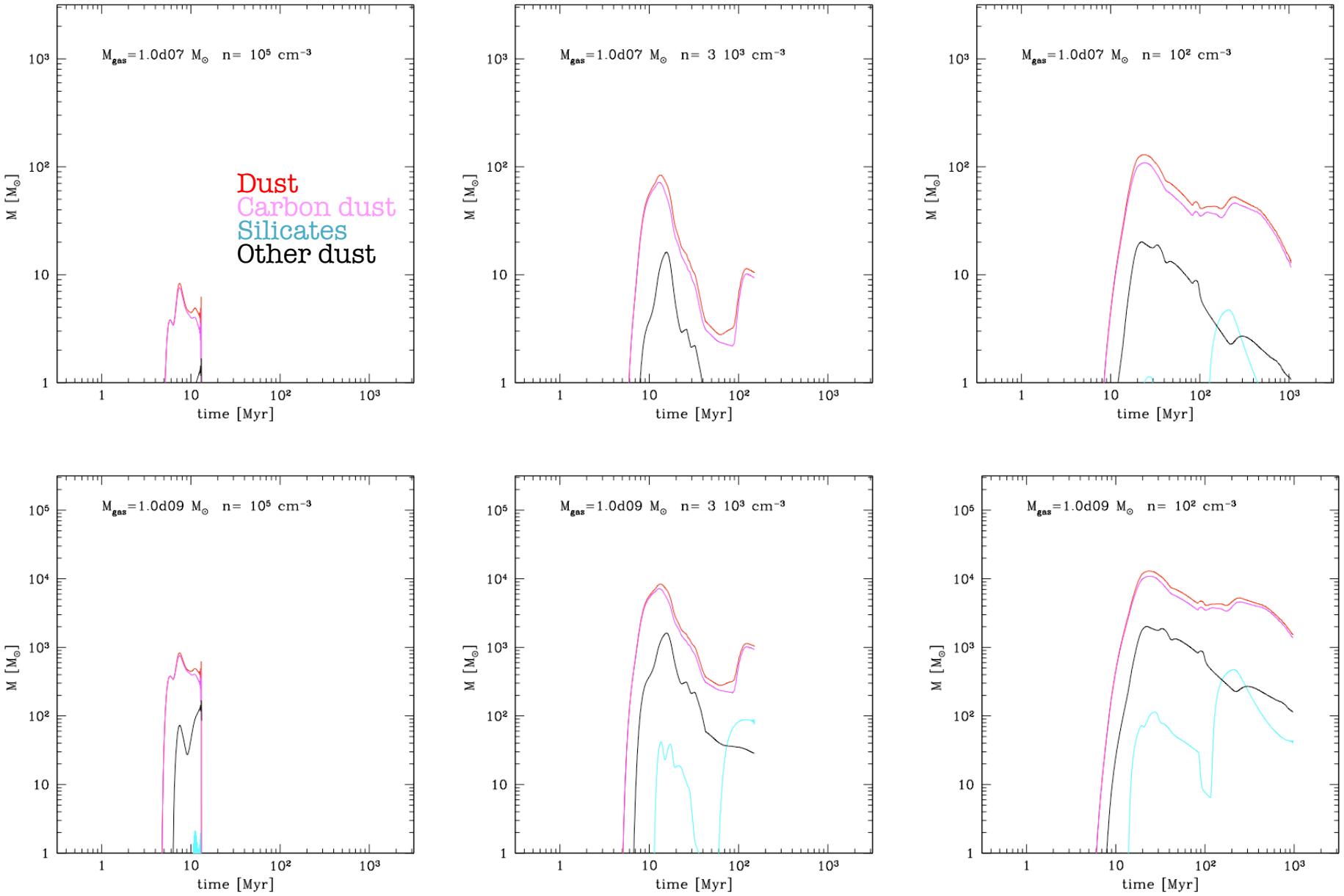



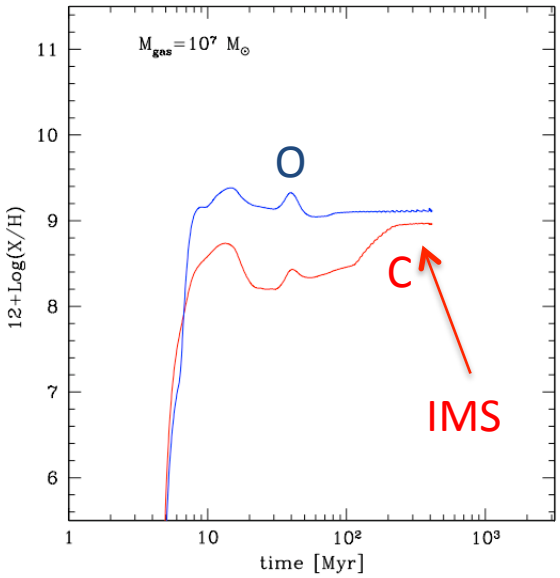



# evolution of dust

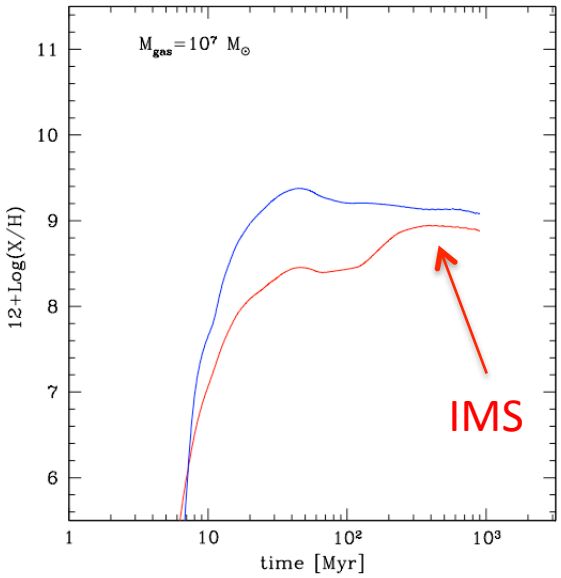


# metallicities

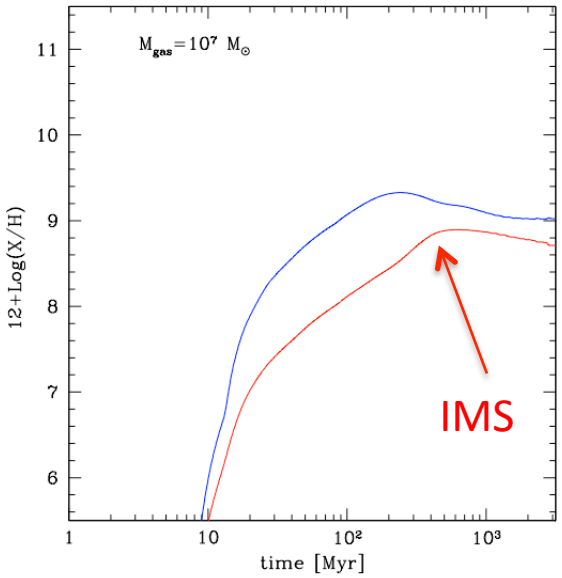
compact




dense



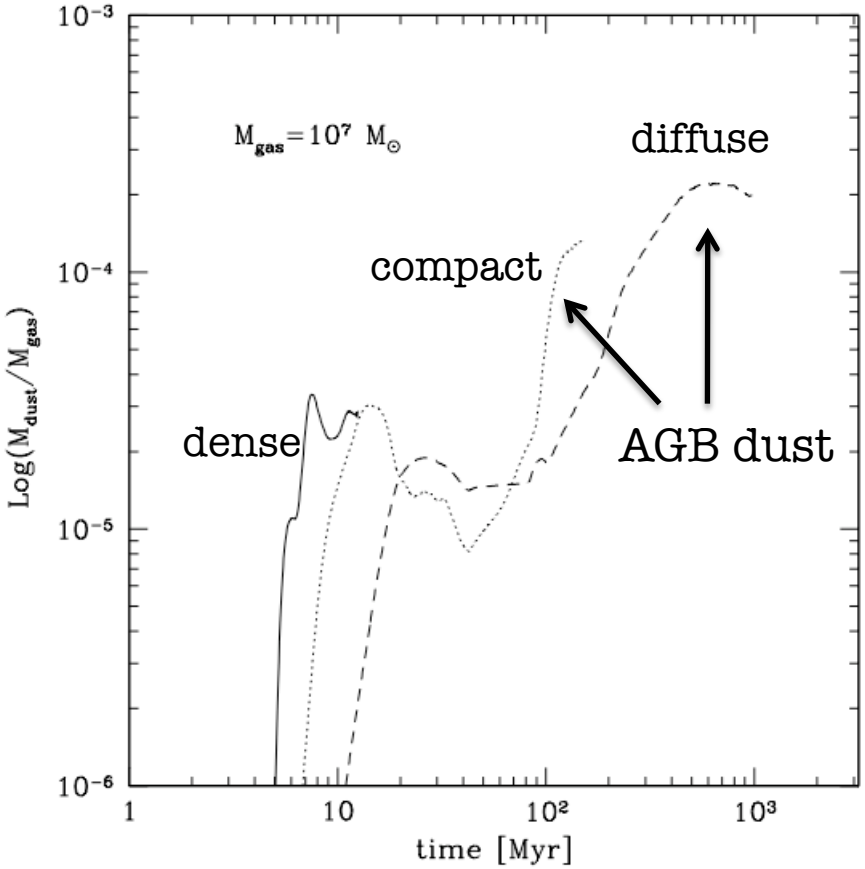

diffuse



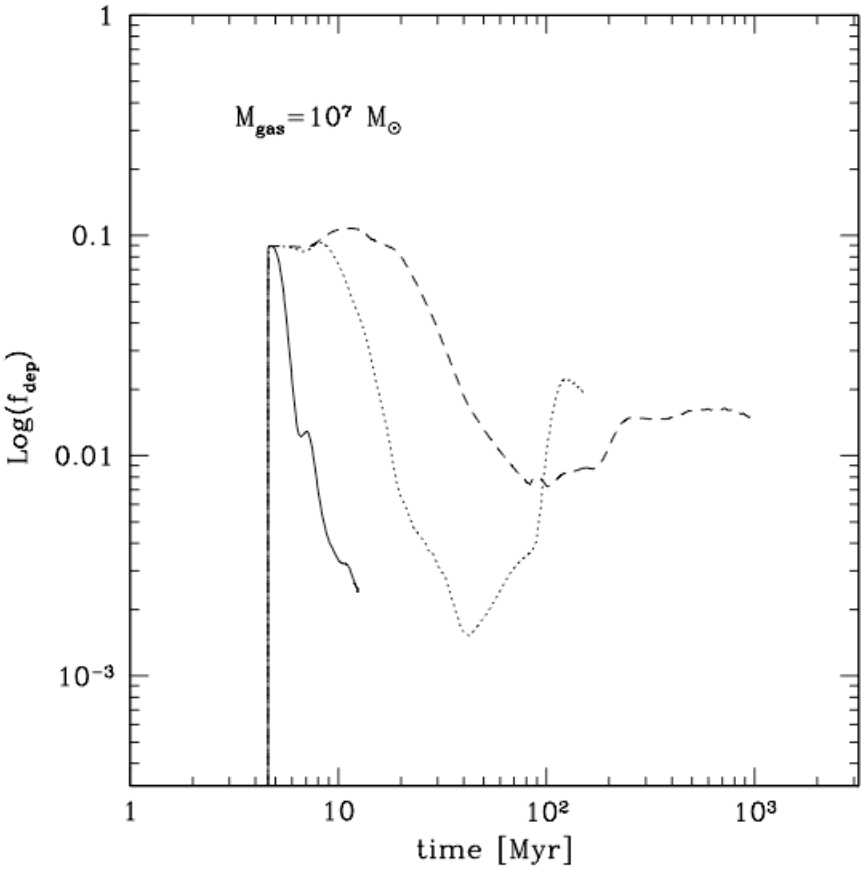

metallicities depend only on the assumed density and NOT on the initial gas mass: same evolution for $10^7$ $M_{sun}$ and $10^9$ $M_{sun}$ models

# dust-to-gas ratios and depletion

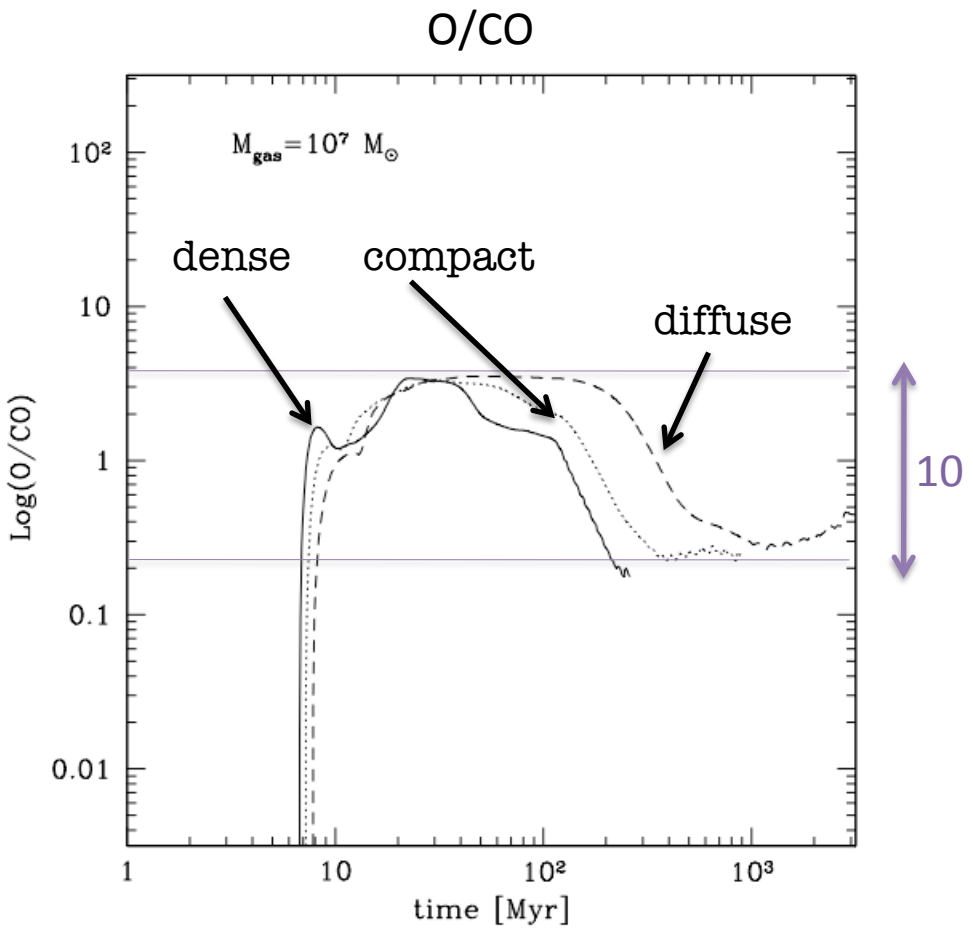
dust-to-gas ratio




Carbon depletion: $f_{dep} = M_{c,dust}/(M_{c,dust}+M_{c,met})$



# molecules


O/CO
$M_{gas}=10^7\ M_\odot$
dense
compact
diffuse
10
Log(O/CO)
$10^2$
10
1
0.1
0.01
1
10
$10^2$
$10^3$
time [Myr]

# possible improvements of the model

Mechanical feedback: $\frac{\mathrm{d}M_{\mathrm{ej}}}{\mathrm{d}t} = \frac{2\epsilon_{\mathrm{w}}\langle E_{\mathrm{SN}}\rangle}{v_{\mathrm{e}}^2}\frac{\mathrm{d}N_{\mathrm{SN}}}{\mathrm{d}t}$.

$$\frac{\mathrm{d}M_*}{\mathrm{d}t} = \mathrm{SFR} = \epsilon_* \frac{M_{\mathrm{g}}}{t_{\mathrm{ff}}},$$

$$\frac{\mathrm{d}M_{\mathrm{g}}}{\mathrm{d}t} = -\mathrm{SFR} + \frac{\mathrm{d}R}{\mathrm{d}t} + \frac{\mathrm{d}M_{\mathrm{inf}}}{\mathrm{d}t} - \frac{\mathrm{d}M_{\mathrm{ej}}}{\mathrm{d}t},$$

$$\frac{\mathrm{d}M_{Z_i}}{\mathrm{d}t} = -Z_i^{\mathrm{ISM}}\mathrm{SFR} + \frac{\mathrm{d}Y_i}{\mathrm{d}t} + Z_i^{\mathrm{vir}}\frac{\mathrm{d}M_{\mathrm{inf}}}{\mathrm{d}t} - Z_i^{w}\frac{\mathrm{d}M_{\mathrm{ej}}}{\mathrm{d}t}$$

# Mechanical feedback

mass of ejected gas

$$\frac{1}{2} M_{ej} v_e^2 = E_{SN}$$

kinetic energy by SN-driven winds

$$E_{SN} = \epsilon_w N_{SN} \langle E_{SN} \rangle$$

escape velocity

$$v_e^2 = GM/r$$

conversion efficiency: 0.002

$10^{51}$erg

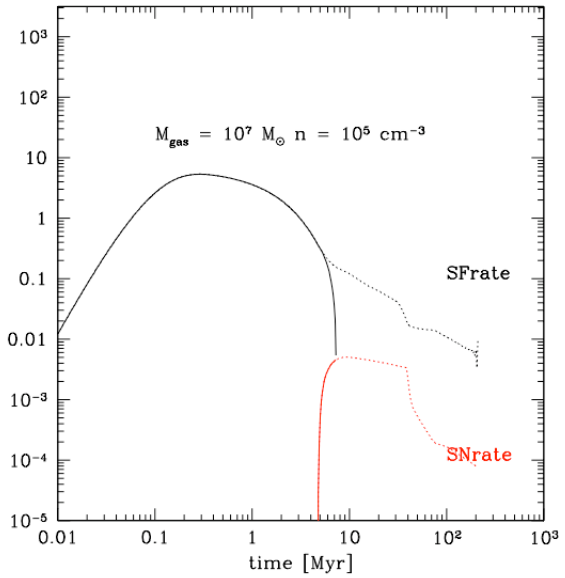
$v_e^2 = G\, M_{gas}/r_{size}$

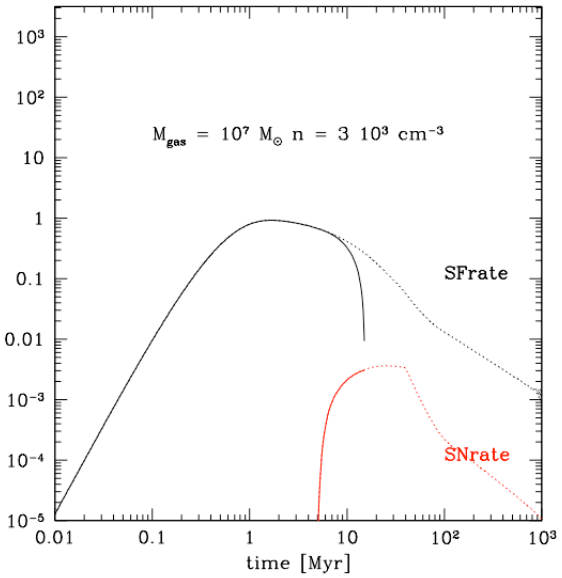
$E_b = ½\, G\, M_{gas}^2/r_{size}$

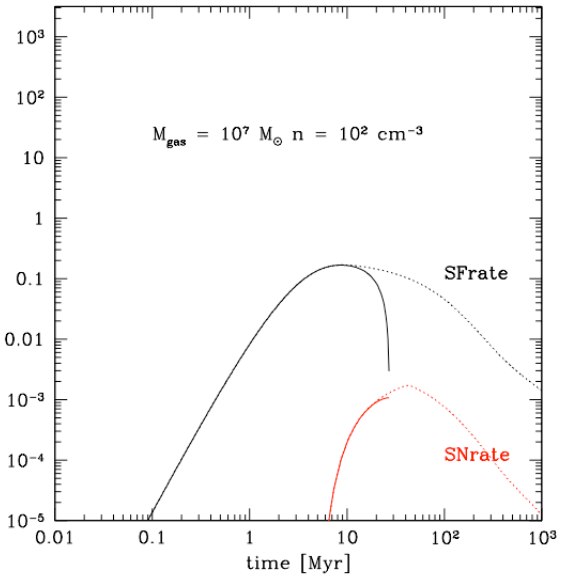
| | dense: $10^5$ cm$^{-3}$ | compact: 3x$10^3$ cm$^{-3}$ | diffuse: $10^2$ cm$^{-3}$ |
|---|---|---|---|
| $10^7$ $M_{sun}$ | $R_{size}$ = 10 pc | $R_{size}$ = 32 pc | $R_{size}$= 100 pc |
| $v_e$ [km/s] | 66 | 37 | 21 |
| $E_b$ [$10^{51}$ erg] | 433 | 134 | 43 |

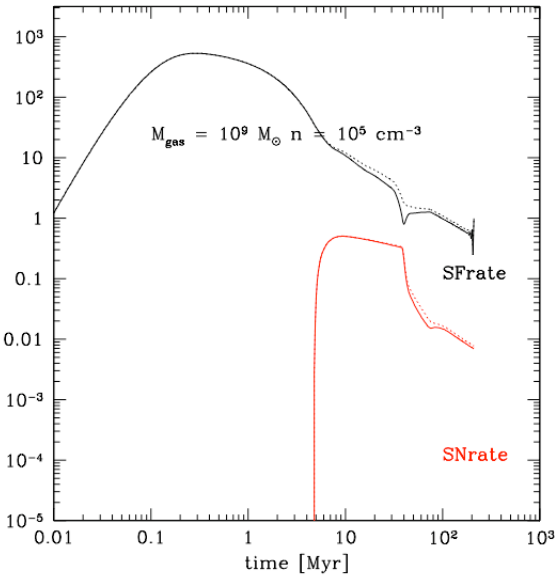
| | | | |
|---|---|---|---|
| $10^9$ $M_{sun}$ | $R_{size}$ = 46 pc | $R_{size}$ = 147 pc | $R_{size}$= 460 pc |
| $v_e$ [km/s] | 306 | 171 | 97 |
| $E_b$ [$10^{51}$erg] | 9.32d05 | 2.89d05 | 9.32d04 |

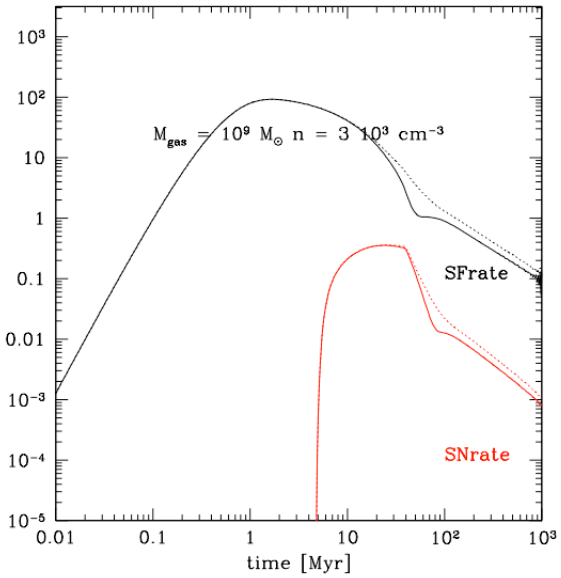
# Outflow models: star formation histories & SN rate

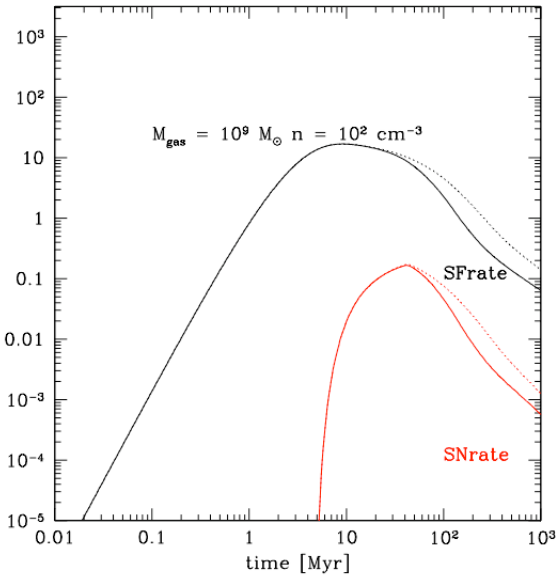


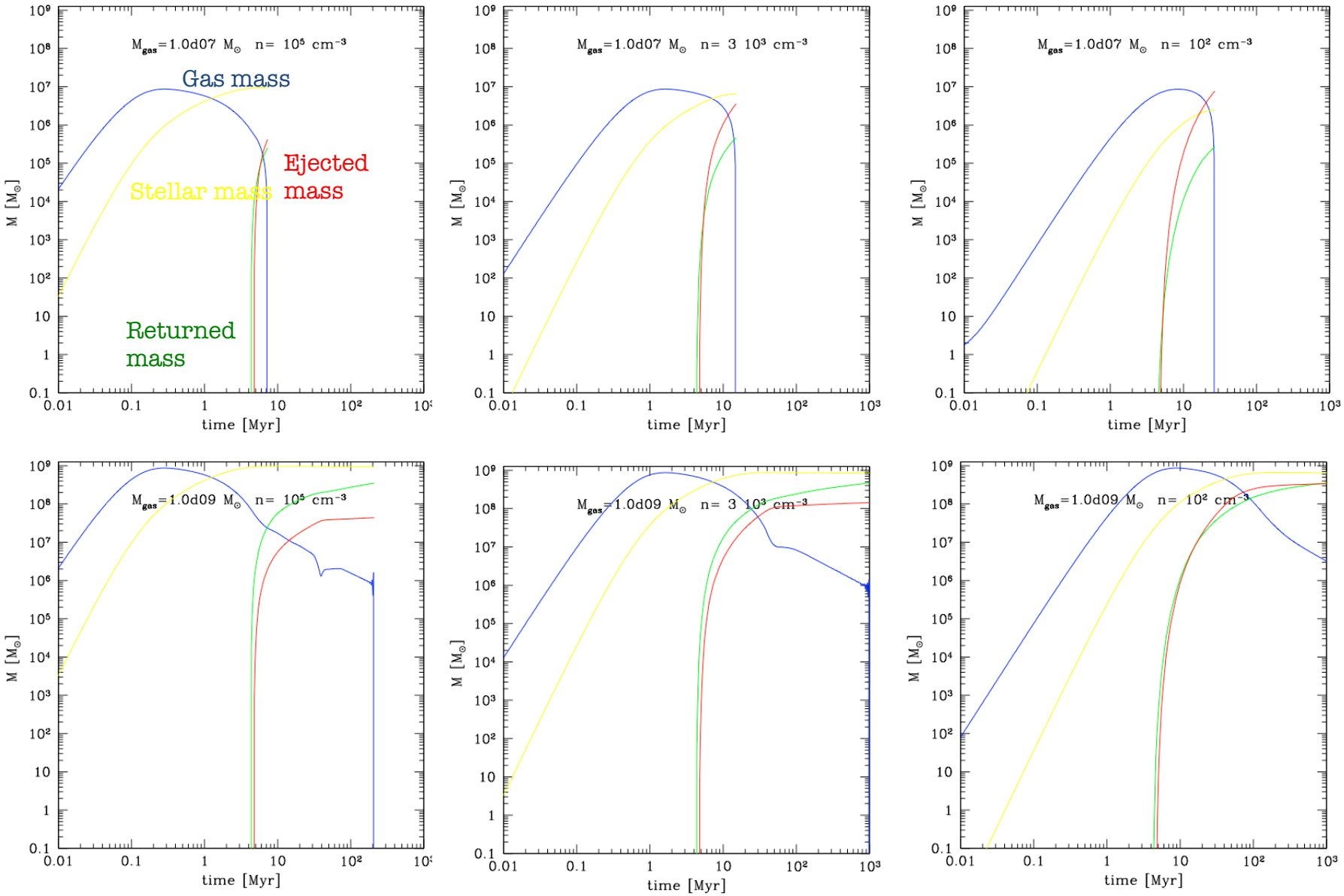



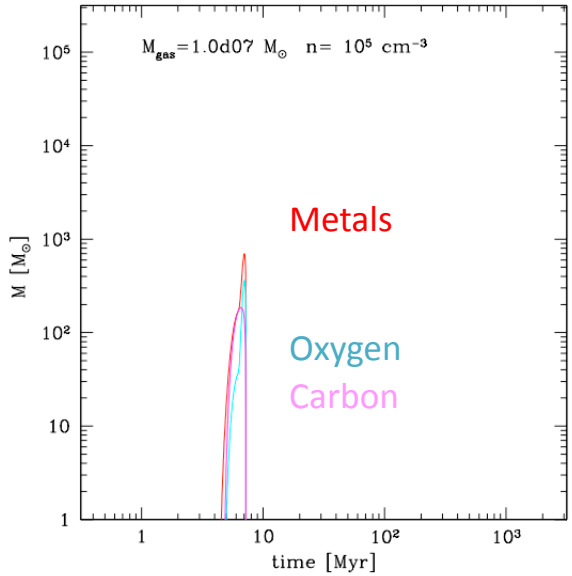



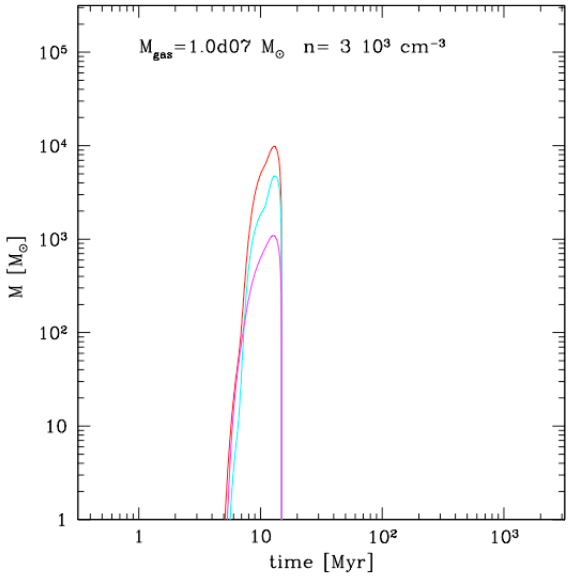



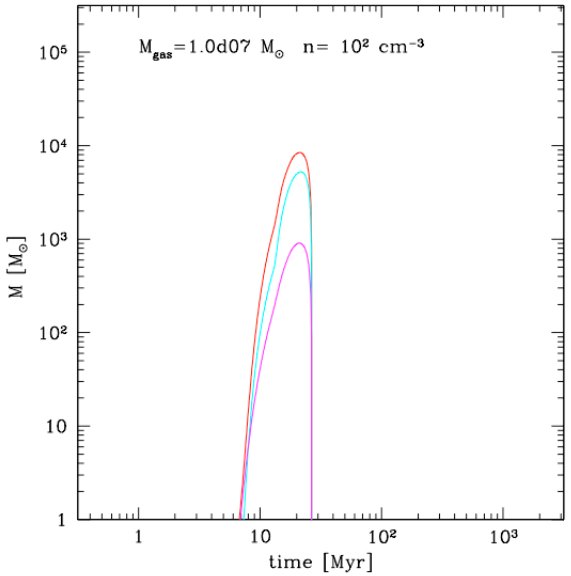
# Outflow models: gas and stellar mass evolution

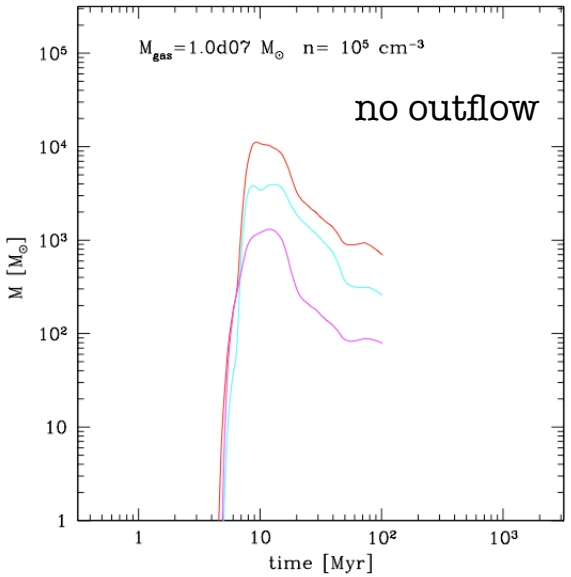


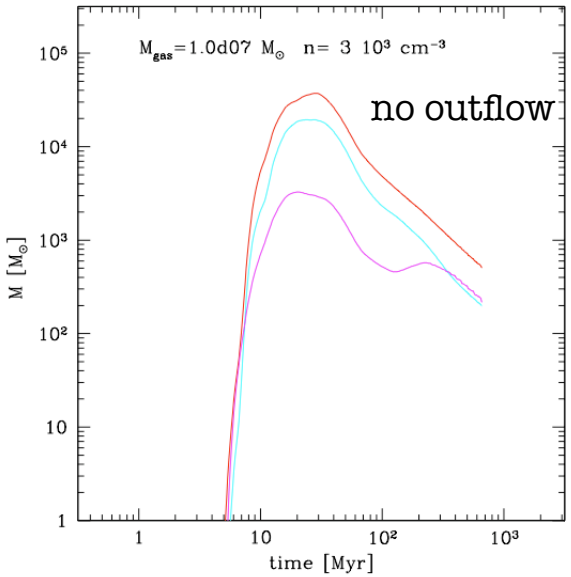
# Outflow models: evolution of metals

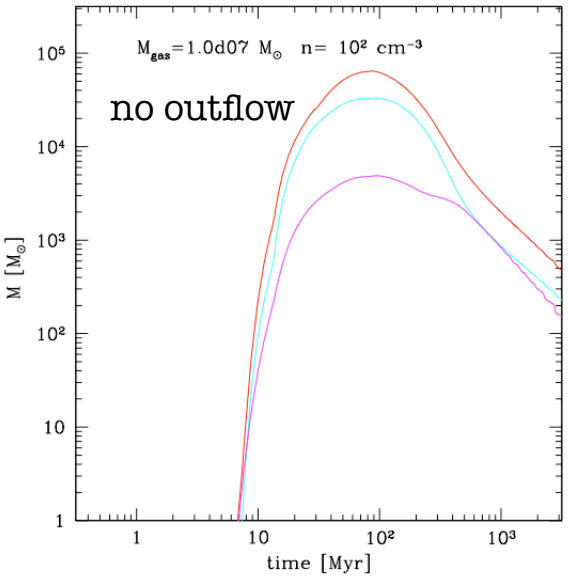


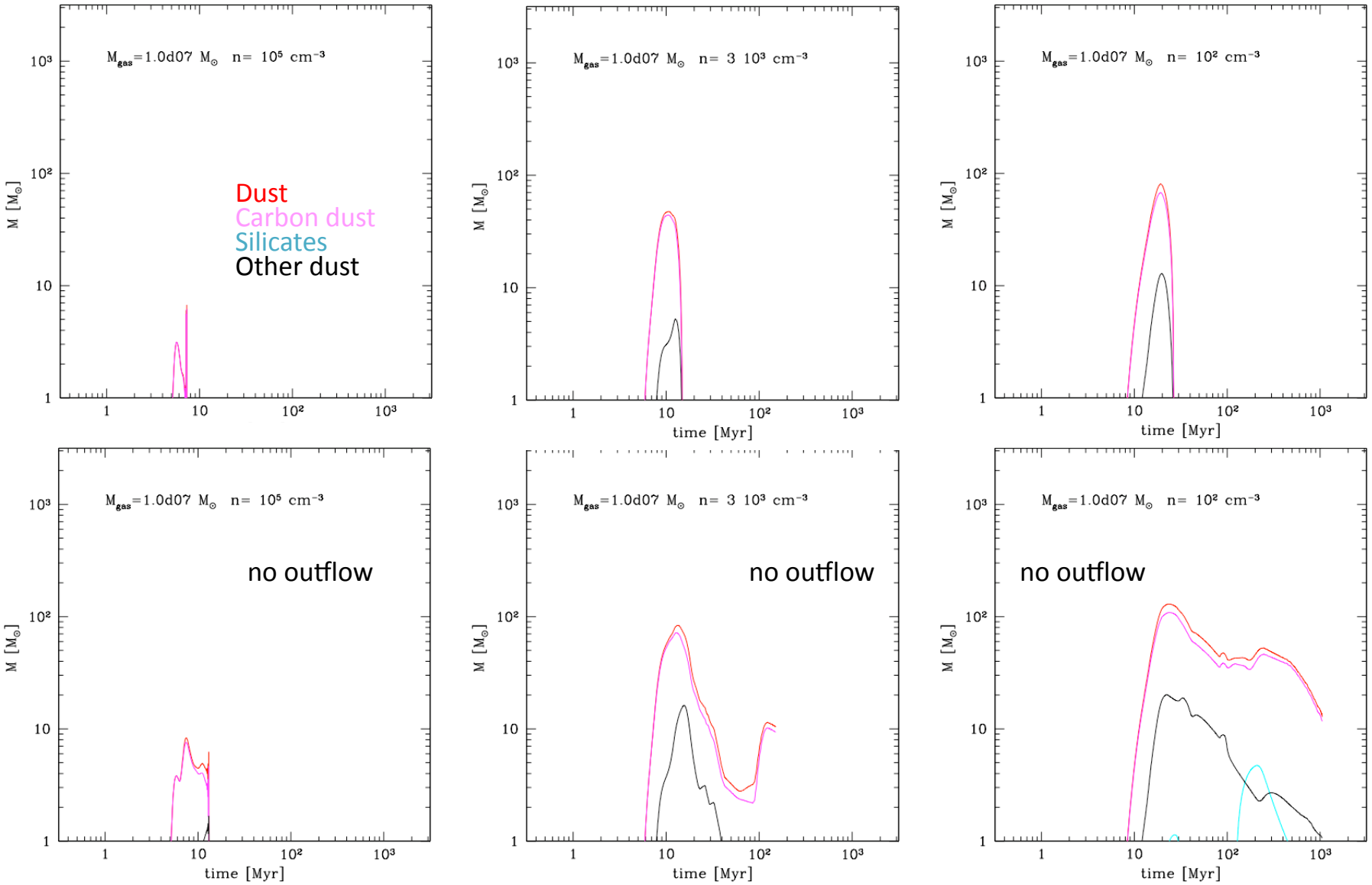



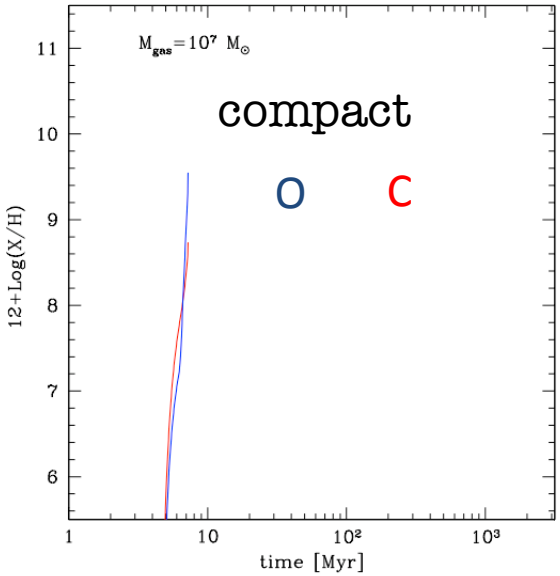



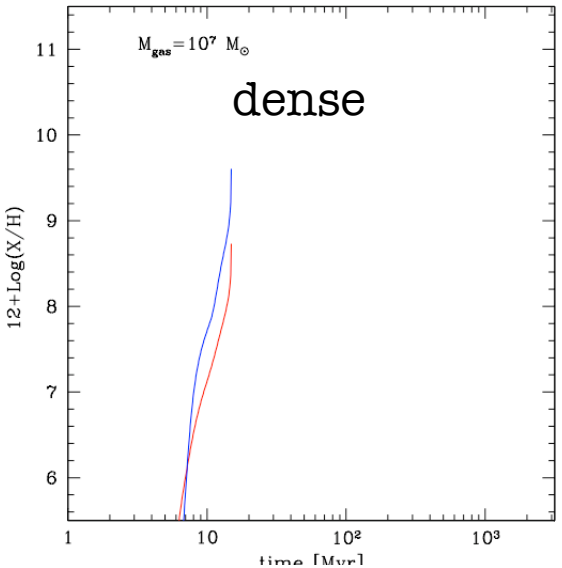



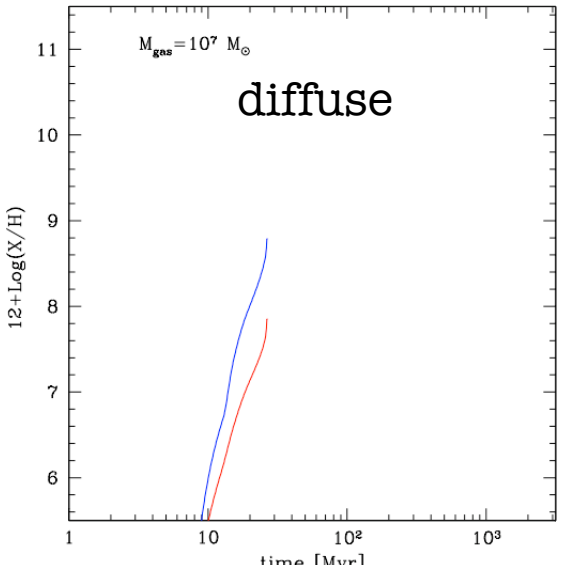
# Outflow models: evolution of dust

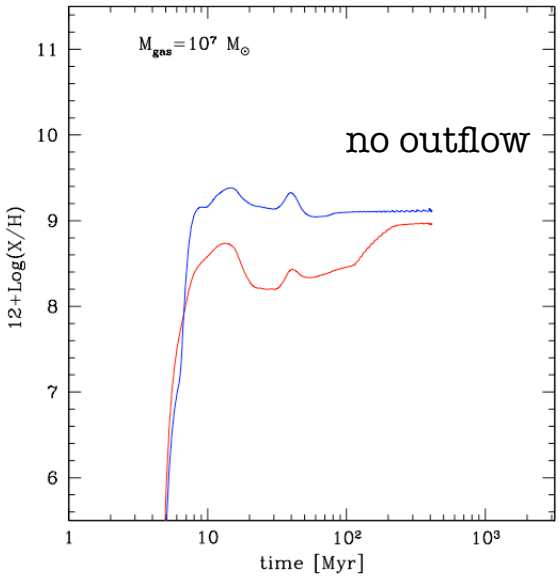


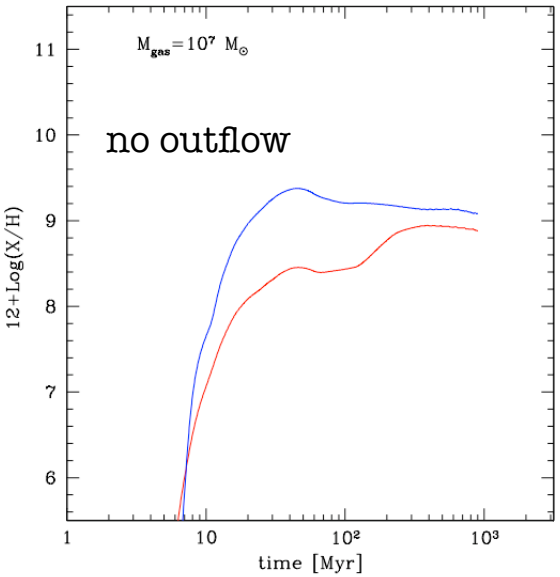
# Outflow models: metallicities

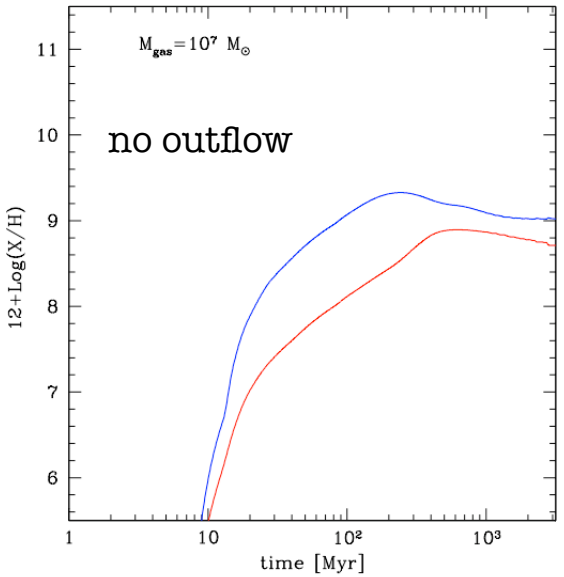


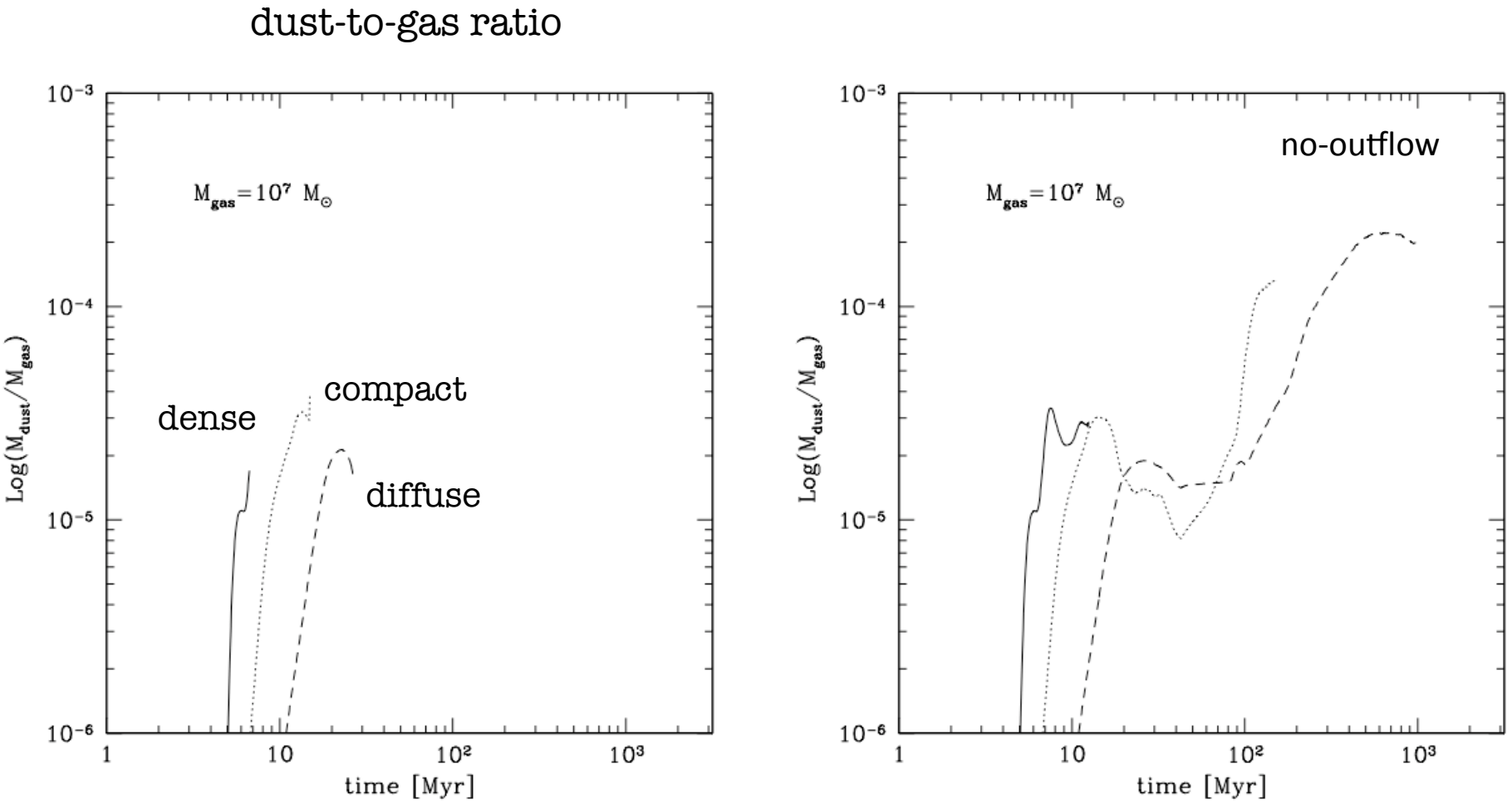



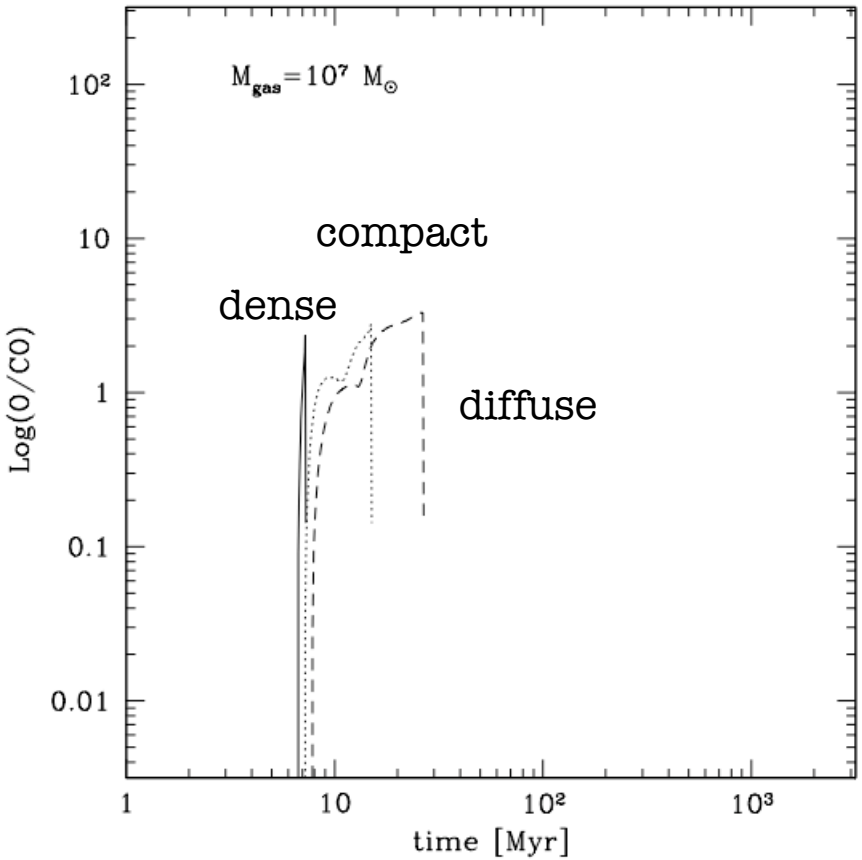



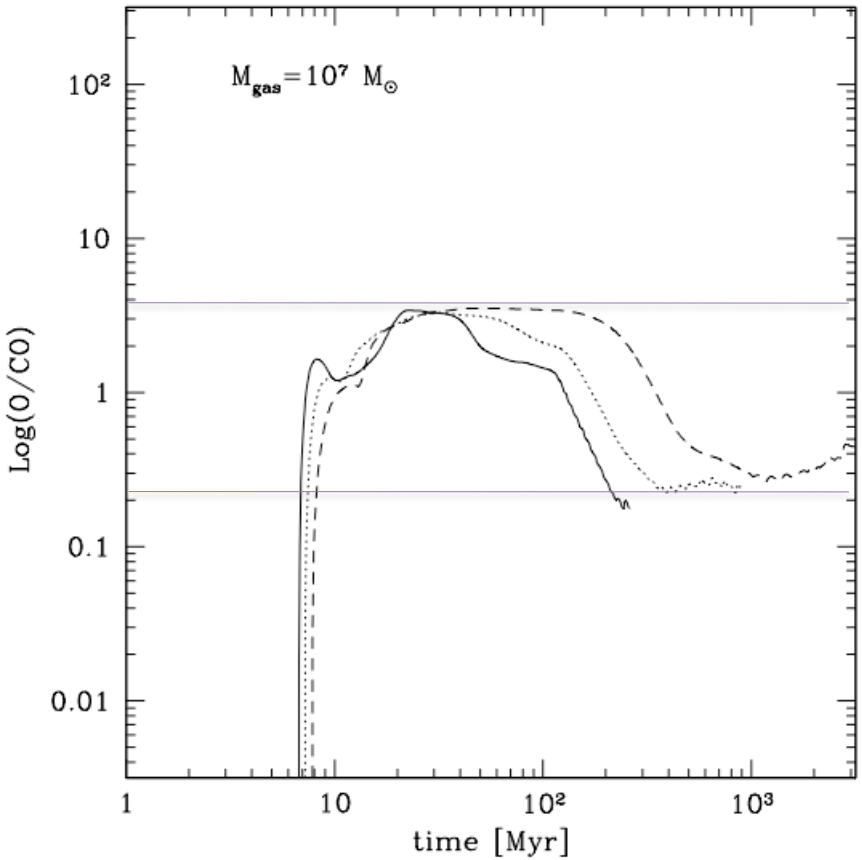
# Outflow models: dust-to-gas ratios



# Outflow models: molecules

O/CO



# Conclusions

Our main contribution to MODULO?

## Dust Yields!

Improvements:
Accretion in MC
SN molecules